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Optimal Matching on Driving System of Hydraulic Hybrid Vehicle

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Abstract

General algorithms can not well solve the problems as complex constrainted design variables and non-function mapping relationship between variables and their constraints. A rule based knowledge-base adaptive simulated annealing genetic algorithm (RBK ASAGA) was used to make optimization matching of hydraulic hybrid vehicle's (HHV) driving system. Simulations on optimized HHV under the circumstance of Simulink with a start-stop-start working cycle according to the corresponding energy have got the consistent conclusion which shows that the proposed RBK ASAGA is reasonable and effective.

Keywords: optimal matching; hydraulic hybrid vehicle; rule based knowledge-base

1. Introduction

The increased severity of energy and environmental issues is making high-performance and environment-friendly vehicles the future direction of the automobile industry. Before the realization of new, cheap and clean energy, hybrid is a practical compromise. To improve energy saving effect is one of the important questions in hybrid vehicle's research. There are many factors that affect energy saving effects, mainly include driving circles, energy control strategy, vehicle construction as well as propelling

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system's main components' parameters matching condition[1, 2]. Among them, the parameters matching problem is the most weighty factor of energy saving effects. Many conclusions made by native and alien researchers show that through key components parameters' optimize matching, the system's whole performances can be promoted effectively without increasing the costs and difficulties of system design, machining and assembly[3-8]. Direct calculation methods, general optimal algorithms or improved optimal algorithms can be used in optimization[3, 9]. The direct way is seriously influenced by optimal sequence; and the general optimal algorithm may not achieve feasible solution or converge at local optimum in restricted periods or iteration times, combinatorial optimization methods are often used to enhance optimization speed and reduce the probability of getting into local optimum. Because the common used optimal algorithms regard the design variables' constraints as an interval or a set, they can not solve complicated or non-function mapping restraints condition well. The rule based knowledge-base was introduced to express complicated or non-function mapping restraints, thus formed a rule based knowledge-base adaptive simulated annealing genetic algorithm (RBK ASAGA), which was used to optimize the matching of a hydraulic hybrid vehicle's propelling system.

2. RBK ASAGA design

The RBK ASAGA uses GA as its main part, and the adaptive rule is used to improve mutational rate at the later period of evolution which reduces the premature convergence probability; the simulated annealing method is used to prolong fitness of objective function which let the outstanding genes keep their advantages during crossover selection, thus improves the evolution speed; the rule based knowledge-base is used to lookup genes that have no precision or orderliness relationship with their feasible regions. The mentioned RBK ASAGA's flow chart is shown in fig.1.

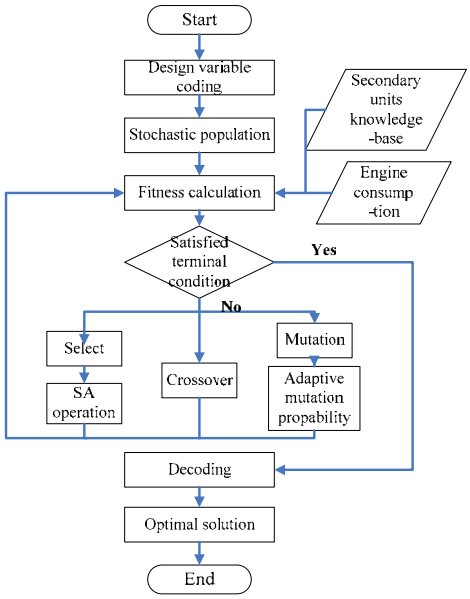

Fig.1 RBK ASAGA's flow chart

2.1. Coding Mode

Because of their complicated coding mode, the binary and Gray coding have to decrease accuracy when the optimal searching space is big[10]. Therefore, float encoding, which expresses the design variables solution space with a certain precision floating number, is used. By this means, the solutions of design variables and their genes are corresponded directly, and the optimal results need no special decoding operation.

2.2. Simulated Annealing Method

The individuals are very different from each other at the early stage of GA operation, so some good ones of them may fill of the population after roulette selection, which causes early mature; while at the last stage, the fitnesses converge, and the outstanding individuals may lose their advantageous, so it is necessary to extend fitness properly. The simulated annealing method was introduced in this research, which divide the heredity progress into two stages with different heredity rules: during the high temperature stage (also the early stage) of GA, the individuals with similar fitnesses have the similar probability to generate offspring; when the temperature descends, the extension effect is enhanced, which makes the fitnesses of individuals with similar fitnesses more different, thus shows the advantageous of outstanding individuals[11].

2.3. Adaptive Mutation Operator

Like the SA method, the adaptive mutation operator changes the probability of genes mutation during evolution incessantly. It makes the mutation probability high during the early stage of the evolution which is helpful to improve the offspring's diversity, and makes the mutation probability low at the later stage to increase the convergence rate and hold a certain mutation probability to avoid local convergence.

2.4. Rule Based Knowledge-base

In some engineering problems, the lookup-table method may be used to ascertain design variables' value when the variables and their ranges have no obvious correlationships or have complicated function fitting relationship while there are discrete test data or table to lookup. The data and tables build up the basement of the knowledge-base, namely the fact layer, and the fact layer combines with criterion (which is also called rule layer) build up a double layer knowledge-base, or a rule based knowledge-base, or rule knowledge-base for short[12-14].

2.5. Object Function

The weight coefficients are used here to combine multi optimal objects into one object, and a unified treatment is required to eliminate influence of different unit, the final optimal object function is

$$F = a_1 \frac{\eta_{\mathrm{r\,max}} - \eta_{\mathrm{r}}}{\eta_{\mathrm{r\,max}} - \eta_{\mathrm{r\,min}}} + a_2 \frac{t_{\mathrm{a}} - t_{\mathrm{a\,min}}}{t_{\mathrm{a\,max}} - t_{\mathrm{a\,min}}} + a_3 \frac{Q - Q_{\min}}{Q_{\max} - Q_{\min}} \tag{1}$$

where a_{i} is the weight coefficient, η_{r} is the energy recovery rate, t_{a} is the acceleration time, Q is the fuel consumption with the unit of L/100km.

3. Example Analysis

To validate that the RBK ASAGA can work reasonable and effectively, a wheel drive hydraulic hybrid vehicle used in transporting is used to be an example to matching its propelling system. The vehicle's main parameters are listed in table1.

Table 1 The main parameters of the example transport vehicle

Parameters	Value	Parameters	Value
Engine rated power	206 kW	Engine max torque	1100 Nm
Wheel radius	0.6 m	Geometry size	8970×2490×2890 mm
Servicing mass	9000 kg	Full load mass	19000 kg
The max velocity	100 km/h	The max slope	30 %
0-50km/h accelerate	20 s	Average velocity	50 km/h

The Matlab language was used to program. The optimal results with compromised coefficients are shown as Fig. 2.

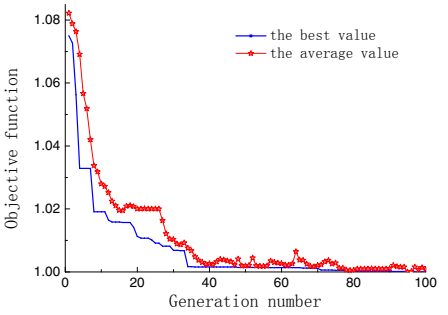

Fig. 2 The evolution progress

The hybrid vehicle's energy recovery rate, fuel consumption saving rate, slope capability and acceleration time are compared with the traditional vehicle, the results are shown in Fig. 3. It shows that the optimized hybrid vehicle has an obvious energy saving and power performances, which proves the optimization is effective.

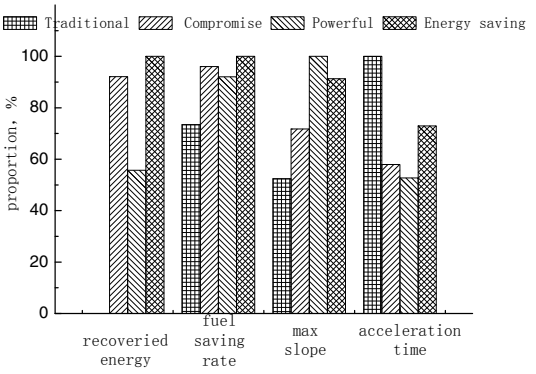

Fig. 3 The comparison of different weight coefficient vehicle

4. Conclusion

The rule based knowledge-base adaptive simulated annealing genetic algorithm was designed to solve the problems that general optimal algorithm can not treat design variables with complex restrains or without function mapping relationship to restrains in hydraulic hybrid vehicle's driving system optimization matching. The proposed algorithm was programmed with Matlab language and the optimal results were simulated in Simulink, the results showed that the proposed RBK ASAGA is reasonable and effective.

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